MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

ETN3136 – DIGITAL COMMUNICATIONS

(TE/MCE)

15 OCTOBER 2018
9:00 A.M – 11:00 A.M
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 8 pages including cover page with **4** Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) State four advantages of digital communications.

[4 marks]

(b) (i) Write and explain the meaning of Shannon's equation.

[2 marks]

(ii) Given that a data stream has bit rate, R_b = 2 kbit/s and is to be transmitted at signal-to-noise ratio (*S/N*) of 13 dB across a channel of bandwidth, B = 2 kHz. Is it possible to achieve error-free transmission? Justify your answer.

[4 marks]

(c) State three ways that a signal can be classified.

[3 marks]

(d) Given a channel with transfer function $H(f)$.

(i) Explain the two channel conditions for a distortionless transmission.

[4 marks]

(ii) An input signal $x(t)$ is transmitted through this channel and the received signal is $r(t) = 4x(t-3)$. Is this transmission distortionless? Explain your answer.

[4 marks]

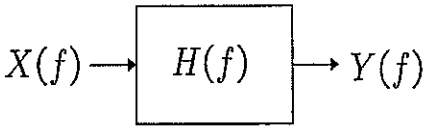
(e) It is common to assume that a communication channel is linear time invariant (LTI).

(i) Briefly explain the conditions for a LTI channel.

[2 marks]

(ii) Given a LTI channel with frequency response $H(f)$. The input to the channel is the signal $X(f)$ and the output of the channel is the signal $Y(f)$, both in frequency domain. If the input signal is deterministic, write down the relationship between $X(f)$ and $Y(f)$. On the other hand, if the input signal is now a random variable with power spectral density $G_X(f)$, write down the relationship between the output power spectral density $G_Y(f)$ and $G_X(f)$.

[2 marks]



LTI channel

Figure Q1(e)

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Question 2

(a) Sampling is used to convert an analog signal into a digital signal.

(i) Explain the Nyquist sampling theorem.

[2 marks]

(ii) A signal $g(t)$ and its spectrum $G(f)$ is shown in Figure Q2(a). Assume no aliasing occurs, sketch the naturally sampled signal and its spectrum.

[4 marks]

(iii) Repeat Q2(a)(ii) but this time with flat-top sampling.

[4 marks]

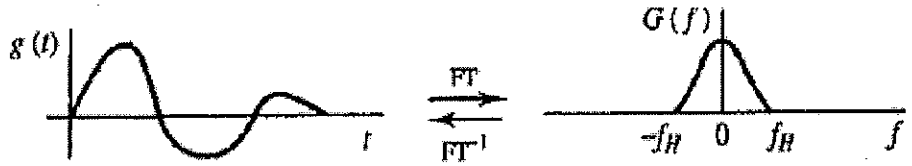

Figure Q2(a)

(b) A pulse coded modulation (PCM) system utilizes a uniform quantizer followed by a 8 bit binary encoder. The bit rate of the system is 80 Mbps.

(i) What is the maximum message bandwidth for which the system operates satisfactorily?

[3 marks]

(ii) Determine the output signal-to-quantization noise ratio when a full load sinusoidal modulating wave of frequency 1 MHz is applied to the input.

[3 marks]

(c) Given an analogue signal $m(t)$ and the sampling signal $s(t) = \sum_{n=-\infty}^{\infty} \Pi\left[(t - nT_s)/\tau\right]$ where T_s is the sampling period, $f_s = 1/T_s$ is the sampling frequency and τ is the width of each rectangular pulse of $s(t)$. Show mathematically that the spectrum of a naturally sampled signal $m_s(t) = s(t)m(t)$ is given by

$$M_s(f) = F\left[m_s(t)\right] = d\sum_{n=-\infty}^{\infty} \frac{\sin \pi nd}{\pi nd} M\left(f - nf_s\right)$$

where $d = \tau / T_s$ is the duty cycle of the sampling signal $s(t)$ and $M(f) = F[m(t)]$ is the spectrum of the analogue waveform $m(t)$.

[9 marks]

Continue...

Question 3

(a) Nyquist's first method must be fulfilled in order to have no intersymbol interference at the receiver. Let $h_e(t)$ be the effective impulse response of a communication system and $H_e(f)$ be its corresponding transfer function. Explain Nyquist's first method and how it impacts on the shape of $h_e(t)$ and $H_e(f)$.

[10 marks]

(b) The line coded signals for a binary stream of 0101011100 are shown in Figure Q3(b) below. Identify these three line coding schemes.

[3 marks]

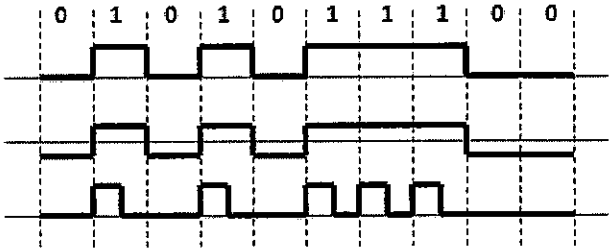

Figure Q3(b)

(c) A communication system implements a QPSK modulation scheme. This system needs to achieve a bit rate of 30 Mbps. The channel where it supposes to transmit its data has a bandwidth of 20 MHz. If a raised cosine filter is used, calculate the roll-off factor, r.

[3 marks]

(d) A 4.8 kbps data terminal is connected to a modem. Calculate the transmission bandwidth, B_T that is required at the modem output for each of the following schemes (raised-cosine roll-off factor, $r = 0.5$).

(i) ASK transmission.

[2 marks]

(ii) FSK transmission (frequency deviation is ±3.6 kHz around the carrier).

[3 marks]

(e) Briefly describe the working principals of a spread spectrum scheme. State the main advantage of this scheme.

[4 marks]

Continue...

Question 4

(a) A binary stream with signal values either a_0 or a_1 is transmitted through a channel contaminated with additive white Gaussian noise. The probability of error for the signal is given as $P_e = Q\left(\frac{a_1 - a_0}{2\sigma}\right)$, where $Q(\bullet)$ is the Q-function in Appendix I and σ is the noise standard deviation.

(i) Write down the relationship between $Q(x)$ and $erf(x)$ where $erf(x)$ is the error function shown in Appendix II.

[1 mark]

(ii) Subsequently, express the above $P_e = Q\left(\frac{a_1 - a_0}{2\sigma}\right)$ in terms of $erf(\bullet)$.

[2 marks]

(iii) Using Q4(a)(ii), find the probability of error when the signal is unipolar NRZ. Repeat this for polar NRZ. Assume an amplitude value of A.

[4 marks]

(iv) Using the expressions found in Q4(a)(iii), find the required signal-to-noise ratio, $\frac{A}{\sigma}$ in order to achieve a probability of error, $P_e = 10^{-5}$ in both cases of unipolar NRZ and polar NRZ.

[4 marks]

(b) A typical digital receiver has a demodulator and detector.

(i) Briefly explain the function of the demodulator and detector.

[2 marks]

(ii) What are the differences between coherent demodulation and non-coherent demodulation?

[4 marks]

(iii) One component in the demodulator is the receiving filter. Describe the impulse response behaviour of an optimum receiving filter which produces maximum signal-to-noise ratio (SNR). What is this optimum receiving filter called?

[3 marks]

(iv) An integrate-and-dump circuit can be used to implement this optimum receiving filter. Explain the working principals of an integrate-and-dump circuit.

[3 marks]

(c) A bandlimited white noise $n(t)$ has power spectral density $G_n(f) = 1\ \mu V^2/Hz$ over the frequency range of -100 kHz to +100 kHz. Find the root-mean-squared (rms) value of the noise power.

[2 marks]

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Appendix I

Tabulated values of Q-function

The Q Function (Gaussian Distribution with $\mu = 0$ and $\sigma = 1$)

$$Q(a) = \int_a^\infty \frac{1}{\sqrt{2\pi}} e^{\frac{-x^2}{2}} dx \qquad Q(a) \cong \frac{1}{a\sqrt{2\pi}} e^{\frac{-a^2}{2}} \text{ for } a \geq 3$$

	3rd Significant Digit									
a	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
0.7	0.2420	0.2389	0.2358	0.2327	0.2297	0.2266	0.2236	0.2207	0.2177	0.2148
0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
1.2	0.1151	0.1131	0.1112	0.1094	0.1075	0.1057	0.1038	0.1020	0.1003	0.0985
1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
3.0	0.0014	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002

$Q(a)$	a
10^{-4}	3.73
5×10^{-5}	3.90
10^{-5}	4.27
5×10^{-6}	4.43

$Q(a)$	a
10^{-6}	4.76
10^{-7}	5.20
10^{-8}	5.61
10^{-9}	6.00

Continue…

Appendix II

Tabulated values of error function

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2}\, dt$$

	Hundredths digit of x									
x	0	1	2	3	4	5	6	7	8	9
0.0	0.00000	0.01128	0.02256	0.03384	0.04511	0.05637	0.06762	0.07886	0.09008	0.10128
0.1	0.11246	0.12362	0.13476	0.14587	0.15695	0.16800	0.17901	0.18999	0.20094	0.21184
0.2	0.22270	0.23352	0.24430	0.25502	0.26570	0.27633	0.28690	0.29742	0.30788	0.31828
0.3	0.32863	0.33891	0.34913	0.35928	0.36936	0.37938	0.38933	0.39921	0.40901	0.41874
0.4	0.42839	0.43797	0.44747	0.45689	0.46623	0.47548	0.48466	0.49375	0.50275	0.51167
0.5	0.52050	0.52924	0.53790	0.54646	0.55494	0.56332	0.57162	0.57982	0.58792	0.59594
0.6	0.60386	0.61168	0.61941	0.62705	0.63459	0.64203	0.64938	0.65663	0.66378	0.67084
0.7	0.67780	0.68467	0.69143	0.69810	0.70468	0.71116	0.71754	0.72382	0.73001	0.73610
0.8	0.74210	0.74800	0.75381	0.75952	0.76514	0.77067	0.77610	0.78144	0.78669	0.79184
0.9	0.79691	0.80188	0.80677	0.81156	0.81627	0.82089	0.82542	0.82987	0.83423	0.83851
1.0	0.84270	0.84681	0.85084	0.85478	0.85865	0.86244	0.86614	0.86977	0.87333	0.87680
1.1	0.88021	0.88353	0.88679	0.88997	0.89308	0.89612	0.89910	0.90200	0.90484	0.90761
1.2	0.91031	0.91296	0.91553	0.91805	0.92051	0.92290	0.92524	0.92751	0.92973	0.93190
1.3	0.93401	0.93606	0.93807	0.94002	0.94191	0.94376	0.94556	0.94731	0.94902	0.95067
1.4	0.95229	0.95385	0.95538	0.95686	0.95830	0.95970	0.96105	0.96237	0.96365	0.96490
1.5	0.96611	0.96728	0.96841	0.96952	0.97059	0.97162	0.97263	0.97360	0.97455	0.97546
1.6	0.97635	0.97721	0.97804	0.97884	0.97962	0.98038	0.98110	0.98181	0.98249	0.98315
1.7	0.98379	0.98441	0.98500	0.98558	0.98613	0.98667	0.98719	0.98769	0.98817	0.98864
1.8	0.98909	0.98952	0.98994	0.99035	0.99074	0.99111	0.99147	0.99182	0.99216	0.99248
1.9	0.99279	0.99309	0.99338	0.99366	0.99392	0.99418	0.99443	0.99466	0.99489	0.99511
2.0	0.99532	0.99552	0.99572	0.99591	0.99609	0.99626	0.99642	0.99658	0.99673	0.99688
2.1	0.99702	0.99715	0.99728	0.99741	0.99753	0.99764	0.99775	0.99785	0.99795	0.99805
2.2	0.99814	0.99822	0.99831	0.99839	0.99846	0.99854	0.99861	0.99867	0.99874	0.99880
2.3	0.99886	0.99891	0.99897	0.99902	0.99906	0.99911	0.99915	0.99920	0.99924	0.99928
2.4	0.99931	0.99935	0.99938	0.99941	0.99944	0.99947	0.99950	0.99952	0.99955	0.99957
2.5	0.99959	0.99961	0.99963	0.99965	0.99967	0.99969	0.99971	0.99972	0.99974	0.99975
2.6	0.99976	0.99978	0.99979	0.99980	0.99981	0.99982	0.99983	0.99984	0.99985	0.99986
2.7	0.99987	0.99987	0.99988	0.99989	0.99989	0.99990	0.99991	0.99991	0.99992	0.99992
2.8	0.99992	0.99993	0.99993	0.99994	0.99994	0.99994	0.99995	0.99995	0.99995	0.99996
2.9	0.99996	0.99996	0.99996	0.99997	0.99997	0.99997	0.99997	0.99997	0.99997	0.99998
3.0	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99999	0.99999	0.99999
3.1	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999
3.2	0.99999	0.99999	0.99999	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

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Appendix III

Fourier Transform Operations

Operation	$g(t)$	$G(\omega)$
Addition	$g_1(t)+g_2(t)$	$G_1(\omega)+G_2(\omega)$
Scalar multiplication	$kg(t)$	$kG(\omega)$
Symmetry	$G(t)$	$2\pi g(-\omega)$
Scaling	$g(at)$	$\frac{1}{\lvert a\rvert}G\left(\frac{\omega}{a}\right)$
Time shift	$g(t-t_o)$	$G(\omega)e^{-j\omega t_o}$
Frequency shift	$g(t)e^{j\omega_o t}$	$G(\omega-\omega_o)$
Time convolution	$g_1(t)*g_2(t)$	$G_1(\omega)G_2(\omega)$
Frequency convolution	$g_1(t)g_2(t)$	$\frac{1}{2\pi}G_1(\omega)*G_2(\omega)$
Time differentiation	$\frac{d^n g}{dt^n}$	$(j\omega)^n G(\omega)$
Time integration	$\int_{-\infty}^{t} g(x)dx$	$\frac{G(\omega)}{j\omega}+\pi G(0)\delta(\omega)$

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